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Precautionary Approach Limit Reference Points for Atlantic Cod (*Gadus morhua*) in NAFO Divisions 4X5Yb and 5Zjm

Points de référence limites conformes à l'approche de précaution pour la morue franche (*Gadus morhua*) des divisions 4X5Yb et 5Zjm de l'OPANO

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ABSTRACT

Fisheries and Oceans Canada (DFO) Ecosystem and Fisheries Management Branch requested
that limit reference points consistent with the Precautionary Approach (PA) be developed for the
cod management units in eastern Canada. At a 2010 zonal science advisory process, the
methodology for calculating spawning stock biomass limit (B_{lim}) reference points for Atlantic cod
in the Gulf and Maritimes Regions was agreed upon and reference points were defined.

Conservation limit reference points (LRPs) were calculated for NAFO Divisions 4X5Yb and 5Zjm
cod based on Beverton-Holt stock-recruitment models.   The PA reference point, B_{lim}, was
calculated as 24,000t for cod in Divisions 4X5Yb and 21,000t for Division 5Zjm.   Estimated
4X5Yb spawning stock biomass (SSB) has been below the LRP since 2002 and was estimated
to be 10,600t at the beginning of 2009.   Estimated 5Zjm cod SSB has been below the LRP
since 1994 and is currently estimated to be 9,260t.

RÉSUMÉ

La Direction de la gestion des écosystèmes et des pêches de Pêches et Océans Canada
(MPO) a demandé que des points de références limites conformes à l'approche de précaution
(AP) soient fixés pour les unités de gestion de la morue franche dans l'est du Canada. Lors
d'une réunion au titre du processus de consultation scientifique zonal tenue en 2010, les
participants ont convenu d'une méthode de calcul des points de référence limites pour la
biomasse du stock reproducteur (B_{lim}) dans les régions du Golfe et des Maritimes et les ont
définis.

Les participants ont calculé les points de référence limites (PRL) de conservation pour la morue
de 4X5Yb et 5Zjm d'après des modèles stock-recrutement de Beverton-Holt. Le point de
référence de l'AP, B_{lim}, se chiffre à 24 000 t pour 4X5Yb et 21 000 t pour 5Zjm. L'estimation de
la biomasse du stock reproducteur (BSR) pour 4X5Yb est inférieure au PRL depuis 2002 et a
été chiffrée à 10 600 t au début de 2009. L'estimation de la BSR pour 5Zjm est inférieure au
PRL depuis 1994 et se chiffre actuellement à 9 260 t.

BACKGROUND

A zonal (Fisheries and Oceans Canada, Gulf and Maritimes Regions) science advisory process framework meeting was held at the Gulf Fisheries Centre, Moncton (NB) on December 6 to 8, 2010, to address a number of analytical questions for Atlantic cod stocks in the DFO Gulf and Maritimes Regions (DFO 2011). In preparation for the Recovery Potential Assessment (RPA) meeting for Atlantic Cod scheduled for February, 2011, in St. John's, NF, Precautionary Approach (PA) biomass limit (B_{lim}) reference points for Atlantic Cod in NAFO Divisions 4X5Yb and 5Zjm were defined.

INTRODUCTION

At the 2002 National Workshop for Reference Points for Gadoids (DFO 2002), five computational methods were retained for defining reference points in terms of spawning stock biomass (SSB). These five methods were:

1. $B_{recover}$: the lowest historical biomass level from which the stock has recovered readily.

2. $Sb_{50/90}$: the SSB corresponding to the intersection of the 50th percentile of the recruitment observations and the replacement line for which 10% of the stock-recruitment (S-R) points are above the line.

3. BH_{50}: the SSB at which expected average recruitment is one half of the maximum recruitment predicted by assuming an underlying Beverton-Holt stock-recruit relationship (i.e. the recruitment that is 50% of the value at the asymptote).

4. RK_{50}: the lower SSB at which expected average recruitment is one half of the maximum recruitment predicted by assuming an underlying Ricker-type stock-recruit relationship (i.e. the recruitment that is 50% of the value at the peak of the dome).

5. NP_{50}: estimate of the lowest SSB where the expected median recruitment is one half of the maximum recruitment calculated by non-parametric analysis (i.e., the recruitment that is 50% of the largest median recruitment achievable at any SSB within the range of historic observations) (DFO 2002, p. 10).

At the workshop it was felt that a comparison amongst the five B_{lim} candidates provided insight into the certainty of advice. If the results were clustered into one region, some level of confidence might be attributed to the result. These methods were applied to 4X5Yb and 5Zjm cod.

4X5Yb AND 5Zjm MODEL FORMULATIONS

There are accepted consensus Virtual Population Analysis (VPA) model formulations for the 4X5Yb (Clark and Emberley 2009) and the 5Zjm Atlantic cod management units (Wang et al. 2009). The most recent assessment of 4X5Yb cod was conducted at the Zonal Advisory Process for Atlantic Cod, February 24 to March 6, 2009 (Clark and Emberley 2009, DFO 2009). The results from the analytical assessment indicated that mortality from causes other than reported landings, including natural mortality (M), of cod 4 years and older increased in 1996. M is currently estimated at 0.76 (Clark and Emberley 2009, DFO 2010).

The 5Zjm Atlantic Cod management unit is assessed annually by the Transboundary Resources Assessment Committee (TRAC). At the time of the zonal framework meeting, the most recent assessment had been conducted in July 2010 (Clark et al. 2010, TRAC 2010). Currently there are two consensus VPA model formulations for the 5Zjm stock: the 'split M 0.2' and the 'split M 0.5' (Wang et al. 2009). Both models are identical except that the 'split M 0.5' model incorporates an increase in the natural mortality rate to a value of 0.5 on cod aged 6 and older. This increase in M is consistent with the perception of reduced fishing effort associated with more restrictive management measures since the mid 1990s (Wang et al. 2009). The 'split M 0.5' model also shows a less severe retrospective pattern than the 'split M 0.2" (Clark et al. 2010). The 'split M 0.5' model was chosen for the purposes of calculating the 5Zjm limit reference point.

4X5Yb LIMIT REFERENCE POINT

Recruitment for 4X5Yb cod was highly variable with no trend prior to 1996 (Figure 1) (Clark 1997). Recruitment above 20 million was common in the 1980s but since the 1992 year-class, no recruitment has approached this level. Recruitment for the 2006 and 2007 year-classes was below average, but about twice the abundance of the very low 2003 and 2004 year-classes (Clark and Emberley 2009). In the past recruitment has been generally higher when biomass exceeded 25,000t (Clark and Emberley 2009).

The limit reference point could be calculated using recruitment data from either the entire time series (1980 to 2007) or the more recent period (since 1996) when biomass and recruitment have been poor. With recent poor recruitment, reference points calculated using the post 1996 data would be much lower than those using the full time series. However, using the more recent data would imply that there had been a regime shift and that the stock-recruitment relationship has changed. There was no evidence that recruitment could not return to higher levels with higher biomass and that there had been an irreversible change in productivity. As a result, the full time series of recruitment data was used.

Using data from 1980 to 2007 and the five methods identified at the 2002 National Workshop for Reference Points for Gadoids, B_{lim} was calculated for 4X5Yb cod. There has been no sustained recovery from a low biomass, so a $B_{recover}$ value could not be identified (Figure 2). The calculation of B_{lim} from the four remaining methods ($Sb_{50/90}$, BH_{50}, RK_{50} and NP_{50}) ranged from 21,000 to 24,000t (Figure 3). Recruitment did not decline at high biomass over the range of spawning stock biomasses observed, and thus the consensus of the zonal framework meeting was to calculate the limit reference point using the Beverton-Holt Stock-Recruitment model. Based on this model, the LRP for 4X5Yb cod was equal to 24,000t of spawning stock biomass (ages 3+).

5Zjm LIMIT REFERENCE POINT

Recruitment for 5Zjm cod, while highly variable, has generally been higher when ages 3+ biomass exceeded 30,000t (Wang et al. 2009). The current biomass is well below this level and there has been consistently low recruitment ($\leq$ 5 million fish) since 1993 (Figure 4). The limit reference point could be calculated using recruitment data from either the entire time series (1978 to 2009) or the more recent period (since 1994) when biomass and recruitment have been poor. As with 4X5Yb cod, because of recent poor recruitment, reference points calculated using the post 1994 data would be much lower than those using the full time series. Since there was no evidence that recruitment could not return to higher levels with higher biomass and that

there had been an irreversible change in productivity, the full time series of recruitment data was used.

Using data from 1978 to 2009 and the five methods identified at the 2002 National Workshop for Reference Points for Gadoids, B_{lim} was calculated for 5Zjm cod. Similar to 4X5Yb cod, there was no evidence for a $B_{recover}$ period (Figure 5). The result from the NP_{50} model (8,000t) differed considerably from the other remaining methods ($Sb_{50/90}$, BH_{50} and RK_{50}), but the other three estimates were more similar, ranging from 20,000 to 24,000t (Figure 6). Recruitment did not decline at high biomass over the range of spawning stock biomasses observed and thus the Beverton-Holt Stock-Recruitment model was preferred. Based on this model, the LRP for 4X5Yb cod was equal to 21,000t of SSB (ages 3+).

CONCLUSION

Conservation limit reference points were calculated for 4X5Yb and 5Zjm cod based on Beverton-Holt stock-recruitment models. The PA reference point, B_{lim}, was calculated as 24,000t for cod in Divs. 4X5Yb and 21,000t for cod in Div. 5Zjm. Estimated 4X5Yb cod SSB has been below the LRP since 2002 and was estimated to be 10,600t at the beginning of 2009. Estimated 5Zjm cod SSB has been below the LRP since 1994 and is currently estimated to be 9,260t.

REFERENCES

Clark, D. 1997. Assessment of cod in Division 4X in 1997. DFO Can. Stock Assess. Sec. Res. Doc. 97/100: 59p.

Clark, D.S., and J. Emberley. 2009. Assessment of Cod in Division 4X in 2008. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/018: vi + 101p.

Clark, K.J., P. Emery, L. O'Brien, Y. Wang, and B. Hatt. 2010. Assessment of Eastern Georges Bank Cod for 2010. TRAC Ref. Doc. 2010/04: iv + 83p.

DFO. 2002. Proceedings of the National Workshop on Reference Points for Gadoids; 5-8 November, 2002. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2002/033: v + 16p.

DFO. 2009. Cod on the Southern Scotian shelf and in the Bay of Fundy (Div. 4X/5Y). DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2009/015.

DFO. 2010. Proceedings of the Zonal Advisory Process for Atlantic Cod for 2009, February 24 - March 6, 2009. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2009/050: xii + 288 p.

DFO. 2011. Proceedings of Gulf and Maritimes Zonal Science Advisory Process Framework Meeting for Atlantic Cod Assessment Models, Medium-term Projections, and Reference Points; 6-8 December 2010. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2011/051.

TRAC. 2010. Eastern Georges Bank Cod. TRAC Status Rep. 2010/03: 9p.

Wang, Y., L. O'Brien, and S. Gavaris. 2009. 2009 Benchmark Assessment Review for Eastern Georges Bank Cod. TRAC Ref. Doc. 2009/07: iv + 108p.
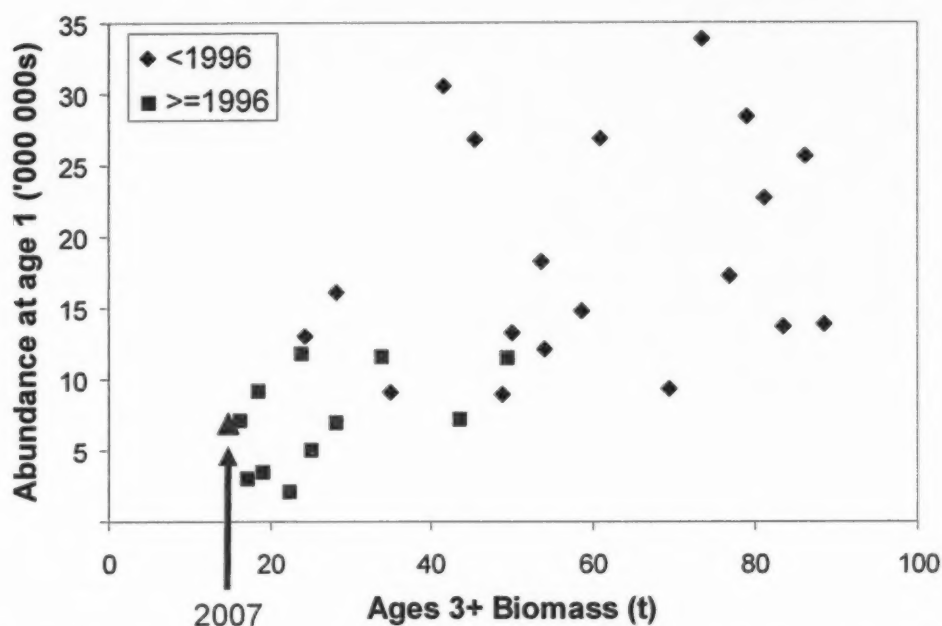
Figure 1.   *Relationship between spawning stock biomass (ages 3+) and recruits at age 1 for 4X5Yb cod. The arrow indicates the 2007 year class (green triangle). Blue diamonds are from before 1996 and the red squares are from 1996 to 2006.*
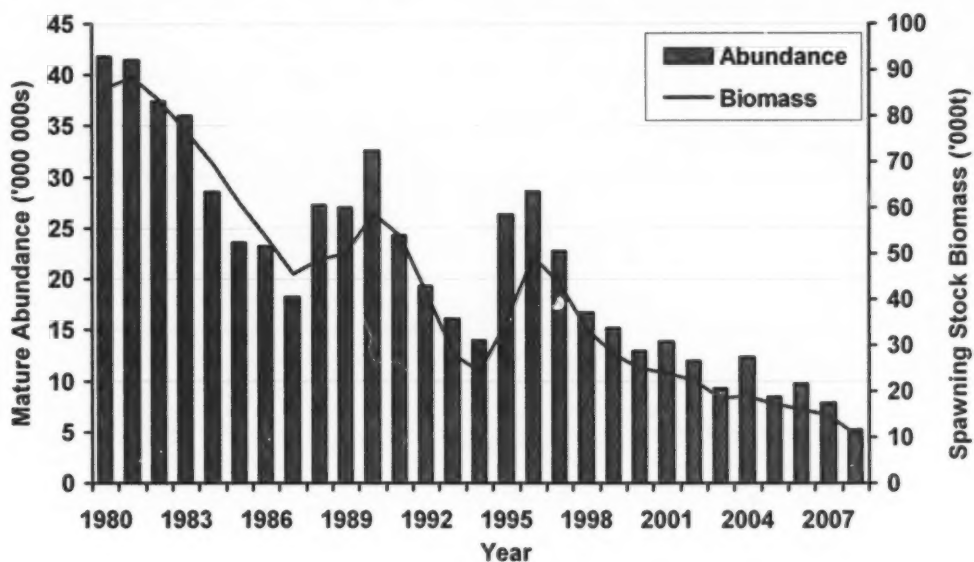

Figure 2.   *Total mature abundance (3+) and spawning stock biomass (3+) for cod in 4X5Yb.*
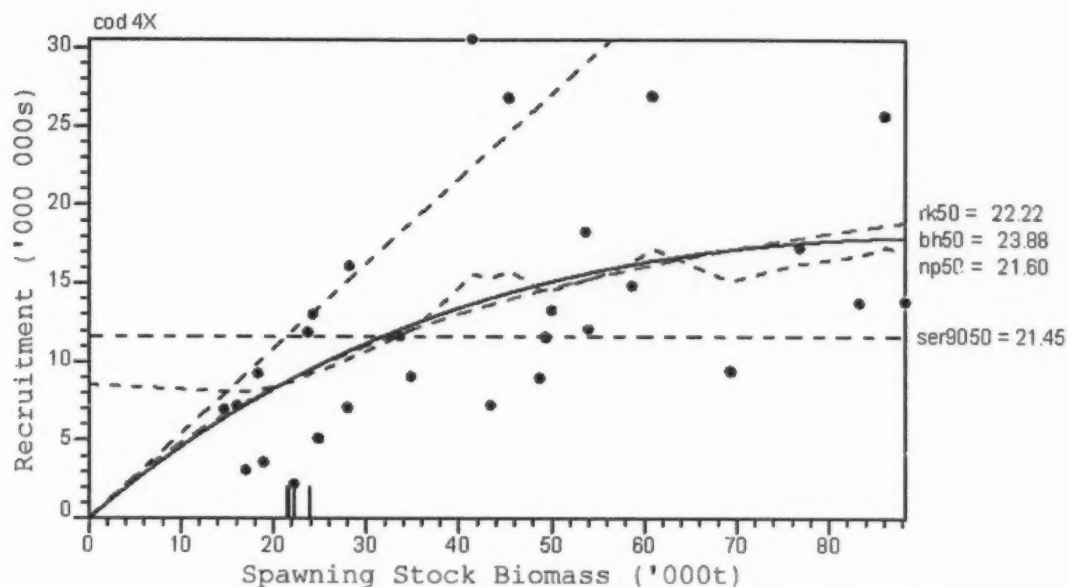
Figure 3. Relationships between spawning stock biomass (ages 3+) and recruits at age 1 for 4X5Yb cod.
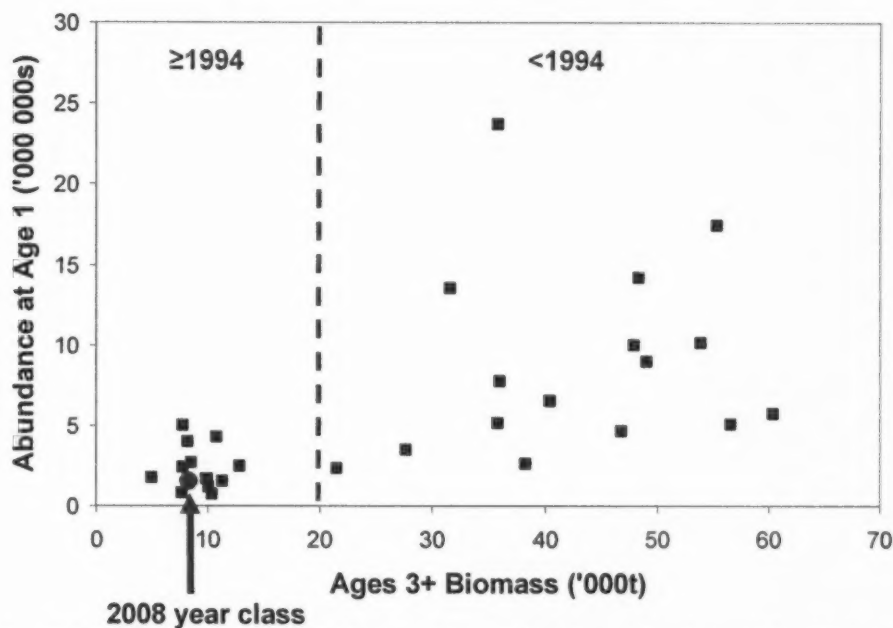

Figure 4.   Relationship between adult biomass (ages 3+) and recruits at age 1 for 5Zjm cod using the "Split M 0.5" model. The arrow indicates the 2008 year-class (red diamond). All data points to the right of the dotted line are from before 1994 and data points to the left are from 1994 to the 2008 year classes.
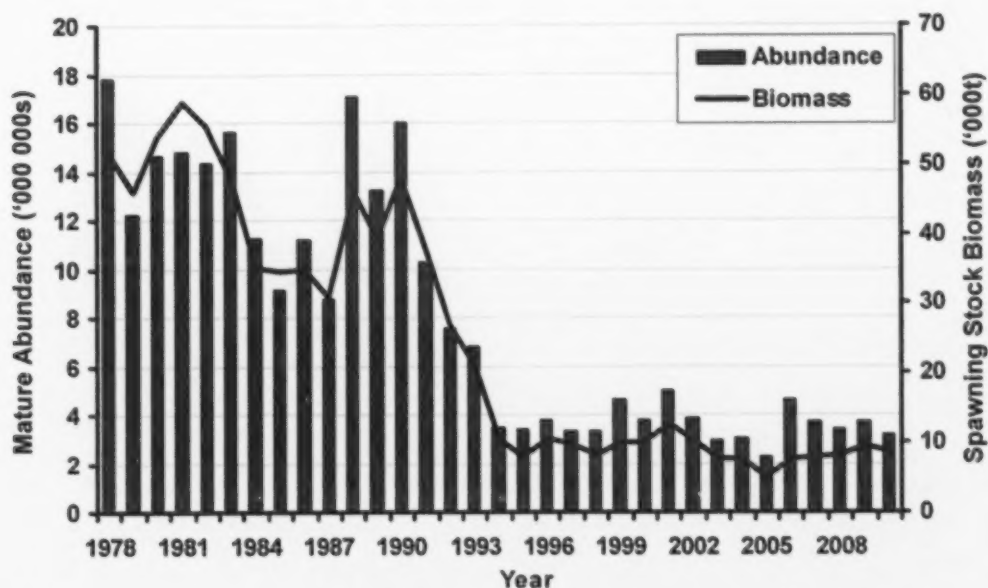
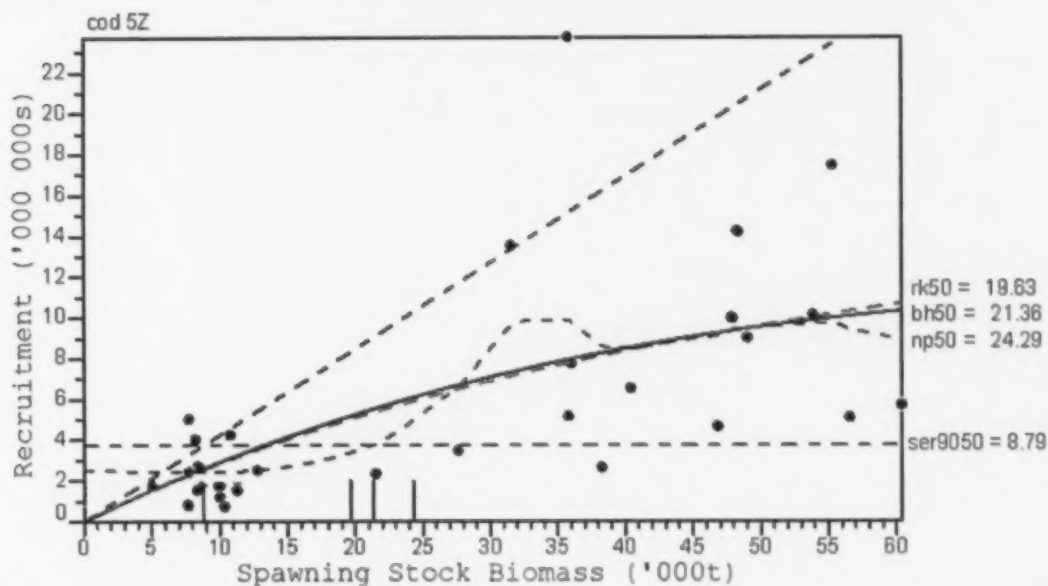Figure 5.   Total mature abundance (3+) and spawning stock biomass (3+) for cod in 5Zjm.

Figure 6.   Relationships between spawning stock biomass (ages 3+) and recruits at age 1 for 5Zjm cod
using the "Split M 0.5" model.